UDC 666.1.053.2.001.24

CALCULATION OF CONTACT PRESSURE IN CUTTING SHEET GLASS WITH A HARD-ALLOY METAL ROLLER

P. V. Popov[1]

Translated from Steklo i Keramika, No. 7, pp. 6 – 7, July, 2001.

The process of cutting sheet glass with a hard-alloy roller is considered. A method for estimating the contact pressure, which is the main parameter characterizing the glass-cutting process, is developed using the methods of contact interaction mechanics. The proposed method can be used to determine the stressed state of glass in cutting and to optimize the glass-cutting conditions employing a hard-alloy roller.

The main method currently used for cutting sheet glass consists of inflicting a cutting line on its surface employing a hard-alloy roller and subsequently separating glass sheets by breaking glass along the specified line. Some of the common defects causing extra losses incurred through broken or defective glass include cracks and chips at the glass edges and glass-breaking outside the cut line [1 – 3]. It is known that the roll cutter generates a system of cracks consisting of a median crack and two radial (lateral) cracks [3 – 6]. The quality of the glass cutting depends on the type and size of these cracks: the deeper the median crack, the better the quality.

The process of obtaining a deep median crack needed for high-quality cutting, in turn, depends on several parameters. Experience in cutting as well as research carried out in this field suggest the following parameters: the value of contact pressure applied by the moving roller to the glass, the geometrical characteristics of the roller, the speed of cutting, the presence of propping liquid, and residual annealing stress value in glass.

The following comment can be made with respect to the last three parameters. The effect of the propping liquid on the cutting process is known to be positive. The stress distribution under a roll cutter and the crack-formation process under the cutting rate, which is accepted in the domestic and foreign glass industries (around 1 m/sec) virtually do not differ from the static process. As for annealing stress, high-quality annealing requires that this stress be reduced to a minimal value, which can be neglected.

Several domestic and foreign researchers studied the effect of contact pressure and geometrical characteristics of the roll cutter (its sharpening angle, radius, etc.) on the quality of glass cutting. The domestic research primarily includes the studies performed at the Tekhstroisteklo Research and Production Association (currently the Saratov Institute of Glass): V. A. Litvinov and L. G. Kopchekchi et al. [1, 3]. Among the foreign authors, this problem was most profoundly investigated by E. Dick and M. V. Swain et al. [4 – 6].

L. G. Kopchekchi, using methods of the classical theory of elasticity, calculated contact pressure, the depth of the roller indentation, and the stresses in glass and determined the conditions for the formation of the median crack. The roll cutter is this case is regarded as a sphere with a known radius. This approach has a drawback. The representation of the roller in the form of a sphere results in the absence of the geometrical characteristics of the roll cutter, in particular, its sharpening angle in the final formulas. And yet it is known from practice that this parameter has a significant effect on the quality of the cutting. The same is concluded in the studies of V. A. Litvinov.

M. V. Swain carried out the most profound research on the problem of glass cutting, employing a hard-alloy roller. Using the methods of destruction mechanics, the author developed a method for determining the contact pressure of the roller upon glass. At the same time, the calculation formulas take into account the geometrical characteristics of the roll cutter, namely, its radius and sharpening angle. However, the calculation formulas contain several experimental coefficients, which, according to Swain, were found by calibration. In doing so, the author does not describe the calibration method; he only indicates several values of these coefficients found for glass of specific chemical compositions under a constant value of the sharpening angle and the roller radius. Thus, the practical applicability of the specified method to calculating contact pressure is limited.

The purpose of the present study was to develop a method for calculating contact pressure in cutting sheet glass employing a hard-alloy roller.

[1] Belgorod State Technological Academy of Construction Materials, Belgorod, Russia.

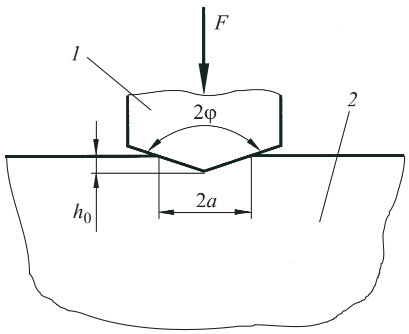

Fig. 1. Diagram of contact interaction between a hard-alloy roller (*1*) and glass (*2*) in cutting.

The known parameters in the process of cutting sheet glass are the physicomechanical properties of the glass and the roll cutter (the Young modulus, Poisson coefficient, microhardness, etc.) and the geometrical characteristics of the cutter (the radius and the sharpening angle). The force applied to the roller is considered statically applied, the force of friction in the roller – glass pair is taken equal to zero, and the glass sheet is considered as a half-space.

As the roller penetrates into the glass to the depth h_0 under the effect of static force F normally applied to the sheet plane, a contact site of size $2a$ (Fig. 1) is formed. Since the microhardness of VK-3 alloy used to make roll cutters significantly exceeds the microhardness of glass, we will neglect the deformation of the roller and will consider it to be totally hard.

Let us determine the contact approach and the contact area. First, we represent the roller as a cone with the vertex angle 2φ equal to the sharpening angle of the roller. In this case, the contact approach in the indentation center in penetration of the roller into the glass can be calculated according to the formula [7]

$$h_0 = \sqrt{\frac{\pi F(1-\nu^2)}{2E\tan\varphi}},$$

where F is the force of pressure on the roller, ν is the Poisson coefficient for glass, and E is the Young modulus.

The contact-site radius in this case is

$$a = \sqrt{\frac{2F(1-\nu^2)\tan\varphi}{\pi E}}.$$

The average contact pressure developed on the contact site is determined as the ratio

$$P_{\mathrm{av}} = \frac{F}{A_{\mathrm{c}}}, \tag{1}$$

where A_{c} is the surface area of the contact of the roller with the glass.

In our case, the contact site is an ellipse [3, 6].The geometrical parameters of the ellipse formed in contact of the roller with the glass are known: the eccentricity is equal to 0.968, and the semiaxis ratio [3] is

$$\frac{b}{c} = 0.22, \tag{2}$$

where b and c are the lengths of the large and small semiaxes of the ellipse.

Taking the length of the small semiaxis of the ellipse equal to the contact-site radius and considering formula (2), we can determine the surface area of the contact (ellipse) as follows:

$$A_{\mathrm{c}} = \pi\sqrt{\frac{2F(1-\nu^2)\tan\varphi}{\pi E}}\,\frac{1}{0.22}\sqrt{\frac{2F(1-\nu^2)\tan\varphi}{\pi E}},$$

that is,

$$A_{\mathrm{c}} = \frac{F(1-\nu^2)\tan\varphi}{0.11E}. \tag{3}$$

By taking into account formulas (1) and (3), the average contact pressure of the roller will be

$$P_{\mathrm{av}} = \frac{0.11E}{(1-\nu^2)\tan\varphi}.$$

A comparative analysis of the calculated data obtained in accordance with the proposed method versus the results of M. V. Swain's experiments demonstrated their good agreement. Since contact pressure is the main cutting parameter, the developed calculation method can be used to determine the stressed state of glass under cutting, as well as to analyze the crack-formation process and to optimize glass-cutting conditions.

REFERENCES

1. V. A. Litvinov, I. A. Maistrenko, E. A. Tarasov, and F. B. Grinberg, "Cutting glass with a hard-alloy roller," *Steklo Keram.*, No. 12, 15 – 17 (1972).
2. L. A. Shitova, N. V. Lalykin, and T. V. Kuznetsova, "Glass edge quality and its strength," *Steklo Keram.*, No. 8, 2 – 3 (1991).
3. L. G. Kopchekchi and L. A. Shitova, "Initiation and propagation of cracks in glass beneath a roll cutter," *Steklo Keram.*, No. 4, 11 – 13 (1996).
4. E. Dick and K. Peter, "Generation of deep cracks in glass," *Am. Ceram. Soc.*, **52**(6), 338 – 339 (1969).
5. M. V. Swain, "The deformation associated with the scoring of soda-lime float glass with a disc cutter," *Glass Techol.*, **21**(6), 290 – 296 (1980).
6. M. V. Swain, "Median crack initiation and propagation beneath a disc glass cutter," *Glass Techol.*, **22**(5), 222 – 230 (1981).
7. I. N. Sneddon, "The relation between load and penetration in the axisymmetric Boussinesq's problem for a punch of arbitrary profile," *Int. J. Eng. Sci.*, **3**(1), 47 – 57 (1965).